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ADDENDUM TO FINAL TECHNICAL REPORT
(IMPLEMENTATION: INDUSTRIAL APPLICATION)

In-Process Quality Control in Apparel Production:
Sewing Defects

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In-Process Quality Control In Apparel Production: Sewing Defects

ADDENDUM TO FINAL TECHNICAL REPORT (IMPLEMENTATION: INDUSTRIAL APPLICATION)

Introduction

The purpose of this addendum is to expand on the in-plant trials of the sewing defect detector based upon the measurement of Thread Motion Ratio or TMR. This introduction contains further background on what was being done technically by the research team as well as further information on the three sites visited. The data and comment sections add further information on the results obtained during the in-plant visits and reaction of the plant operators and management to this system. Our direct contact person(s) at each facility varied considerably. The research team interacted with a middle manager, a head mechanic, an electrical engineer, a vice-president of R & D, and a training department head. Each brought a different perspective to how the sewing defect detector should interact with the sewing process and sewing operator. So that this document may be readable on its own, some basic background is given. That background is directly related to what happened in the three plants visited.

Background

Going into the plants, several points had been considered. Among these is knowledge that TMR measurement is subject to variability inherent with sewing. TMR is by definition the (time) period of flight of the top sewing thread over the period of one sewing machine cycle. This ratio assists normalizing the time of thread motion against sewing machine speed. By hand measurement, TMR has been shown to be linearly related to actual length of thread consumed. The actual length of thread consumed is what is variable from stitch to stitch. Even under controlled laboratory conditions, lockstitch sewing has inconsistent consumption of thread from one stitch to the next. This may be due to changes in finish on the sewing thread or how the needle strikes

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the fabric or a number of other causes. At any rate, plant trials anticipated that conditions would be no better and probably worse than laboratory conditions. The measurement of TMR is based upon averaging groups so that if data from one plant is more subject to variation than another, then the group size may be modified to give more consistency to data values. The use of averages is also dictated by consideration of the statistics of in-plant measurements. Even if the data were not normally distributed, the averages of the data should approach normality. This is a tenet of the Central Limit Theorem. On the other hand, if averages are too large, all variations are hidden, including many that are due to defective sewing conditions. This had been learned in the lab on the JUKI lockstitch machine. Therefore, the plant trials used groups of nine stitches. Confidence had been established that with this group size, limits of + or - four standard deviations could be used with low probability of false indication.

A normal plant sewing machine operates at 4000 RPM or above. This is equivalent to 240,000 stitches per hour. While machines are not used constantly, it still is obvious that the period to obtain a million stitches may be as short as one shift. The probability of false indication has to be small, i.e., one or none per shift, if the defect detector is to be acceptable. The microprocessor has been programmed to accept as variables the number of stitches in a group average and the number of standard deviations range to the upper and lower limits. Nominal starting values are five stitches to average and four sigma limits. During the plant trials a group size of nine was taken because this tended to smooth the visual output on the Mac monitor. Larger group size is associated with smaller range in the four sigma limits. There is benefit to smaller group size, e.g., five, in that this effectively acts like a sensitivity increase. Two or three errant stitches are more likely to be detected.

During the in-plant trials, a Macintosh Powerbook portable PC with external color monitor was interfaced to the microprocessor based defect detection system. LabView is a program that can take values from an external source via its own board slot or via a common

serial port (similar to the COM1: or COM2: PC ports or Mac serial port) and plot them. This was used on data sent via the serial interface of the Mac from the microprocessor board. The purpose of doing this is to provide the observer with a visual indication of what was happening with each group of stitches. It makes the process of explaining what is happening on site easier.

The purpose of the in-plant demonstrations was several fold. Ultimately the goal was receiving feedback on the defect detector's design, noting any improvements that are needed to make the unit commercially desirable and feasible. Objectives within this framework include having the plant personnel understand just what the detector system does and how it would function in the plant. Secondly, the application of the device to a plant's sewing machine in a production environment brings out any deficiencies with respect to ability to handle plant noise in the electronic sense and non-standard sewing conditions (mechanical noise). This is part of the need to test adaptability of the unit. Each brand of sewing machine and each different machine type with respect to stitch type has a somewhat different external geometry and method of thread-up. The team needed to know what physical barriers might arise when the pressure was on for performance.

Fortunately, advance preparation made the in-plant trials generally a smooth operation. For example, the piezoelectric device in the Eltex thread motion sensor needs isolation from the sewing head frame or else signal swamping mechanical vibration is transmitted to the Eltex unit. A strong double backed foam tape was found to perform this duty. The tape's adhesive adheres so well to the machine that masking tape was used in the plants being visited to avoid leaving unsightly adhesive marks on the test sewing heads.

Also, the three phase power supply for sewing plants usually comes in overhead with the floor free of normal wiring. To serve the power needs of the test, some 200 feet of extension cord, spike suppressing multiple outlets and distribution cords were brought to each plant site. As it turns out, it was a necessity at each site in order to supply the power needs of the test equipment.

The set-up time at each site was about two hours. The diagnostic equipment and spare cables / sensor / PC were available should a signal be lost, but never were needed as the tests proceeded without flaw from a technical point of view. The machines used for the test were selected by the representative from the sewing plant accompanying or assisting with the trial.

Industrial Interaction

Interaction described below includes a first test run at the Southern Tech Apparel Demonstration Center, a visit by Coats American at the Apparel Laboratory at Georgia Tech, and three on site visits to plants of Camel Manufacturing, Levi Strauss, and Russell Corporation.

Southern Tech Apparel Demonstration Center...

Rob Shoenborn and Dr. J.L. Dorrity transported the system to Marietta, GA in order to learn about any set-up difficulties on a strange sewing head before going to plant sites for the same purpose. A Pfaff lockstitch machine was selected for the test and Howard Pettigrew provided mechanical assistance with machine operation. There were problems associated with machine vibration whose solution occupied a majority of the test time. This led to using a foam double backed isolation tape for mounting the Eltex sensor. When the fact that vibration was causing the "bad" data at Marietta became known, isolation was provided and data equivalent in quality to lab data was obtained. No data sets recorded at this test have survived for incorporation in this addendum. An important point is that nothing was unusual about the "good" data collected at the Apparel Demonstration Center. This meant that the brand name of machine did not influence the data collected. This was an important conclusion to success in the upcoming trials in sewing plants.

Coats American thread sewability tests...

Coats American is the same company which has been referred to as Coats & Clark in the past. A major industrial sewing thread supplier was acquired by Coats & Clark, which was already the leader in the supply of consumer sewing thread and accessories. The research center for this company is located in Toccoa, GA. For time convenience, Gordon H. Broome, Director of Research, and J. Keith Powell, Development Manager, came to the Apparel Lab at Georgia Tech to do a study of threads known to be of good sewability and of poor sewability. This knowledge of thread characteristics resulted from information learned at commercial sewing plants through returns. A rapid test for thread performance would be of benefit to both government contractors and to commercial sewing plants. This is an industry wide problem, not restricted to one thread manufacturer. The poor sewability thread had passed the normal battery of quality control tests and had been released for general use.

Results of the work with Coats American were consistent and are represented in the data of Figure 1. following on the next page.

Rob Shoenborn and Dr. Dorrity interacted with the Coats American team. Their questions were answered with respect to how this system worked and what future plans may exist for this system. They expressed interest in being informed when the device became commercial.

The people at Coats American also offered their assistance with sewing thread should a particular research need arise in the Georgia Tech Apparel Lab. This device appears to be responsive to a need that has existed for a long while. A go - nogo test of sewability can be added to the other quality tests as part of normal production testing. It may help in the resolution of sources of the inconsistency as well. Three threads are shown in the figure. Two acceptable and the last unacceptable.

=> normal threads <==> poor sewability <=

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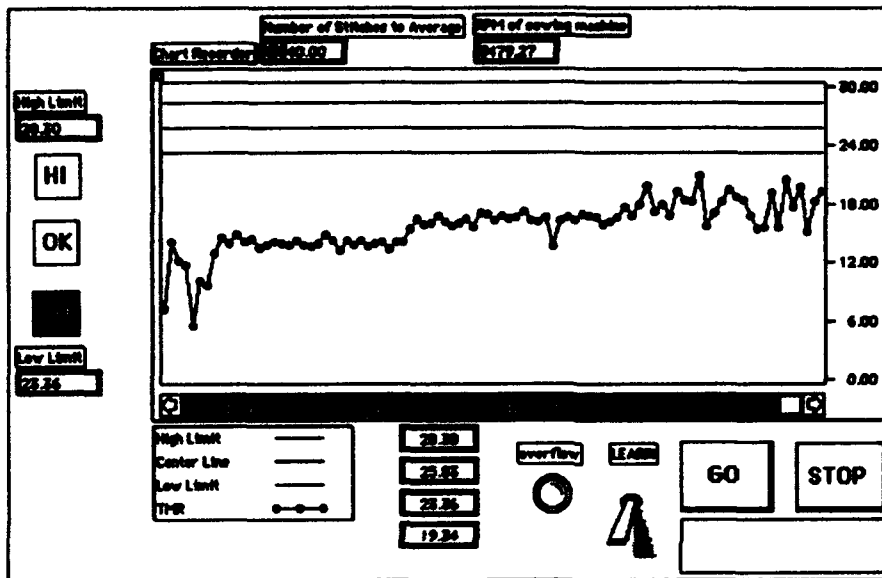


Figure 1. Coats Sewability Test Results

Figure 1. shows that the poor thread yields a highly variable thread consumption in the groups of stitches. The TMR values are variable for reasons that are not certain at this time. Speculation is that thread uniformity in mass per unit length over the short term and finish variation over the short term are probable causes. Coats is anxious to follow up with commercial versions of the defect detector when such might become available.

Visit to Site #1 : Camel Manufacturing

Camel manufacturing is located in LaFollette, TN and is a government contractor producing large tents for the military at the time of the in-plant trial. Contacts at Camel included Chris Arnold and Mark Lester. The machine selected for testing was a lockstitch machine used to sew an inner lining fabric. The particular seam sewn was some twenty feet in length, running from a peak at a pole support across the ceiling to a side wall. All fabric was supported on large tables of some 800 sq. ft. in area at about 29 inches off the floor. The sewing head was in the center of this area, and was adjacent to connecting sewing stations. All elements of the tentage were sewn or assembled here such that finished units were packaged for shipment.

Power cords could not be tolerated on the working surface where fabric panels were handled. Therefore, power for the Mac, its monitor, and the detector were led from the nearest power source under the table to the sewing head. The detector only draws about one to two watts of power on its own. This could easily be taken from the sewing head's power in a stand alone system. Here the demonstration and explanation of the concepts required more graphical capability offered by the monitor. During the visit a group of eight military officers and civilians taking a general tour of the site stopped for review of the demonstration. Seeing this was not the main purpose of their visit, but the information did elicit questions and understanding of what the work intended to do as well as about the DLA support of the work. It seemed inappropriate to elicit names or the purpose of their visit.

Generally, there were no unusual occurrences technically during this visit. When the bobbin ran out, there was immediate reaction. When the seam failed to fold properly, there was a low limit signal due to the reduced thread consumption in the seam. This is illustrated in Figure 2. following.

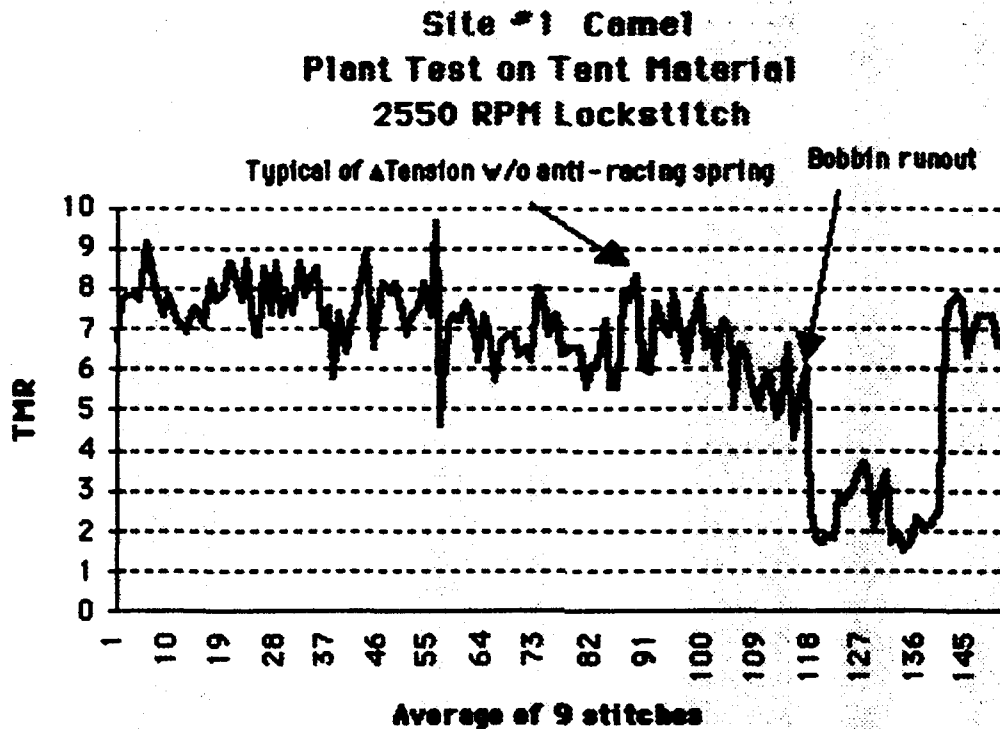


Figure 2. Camel Mfg. Bobbin Runout Data

This figure illustrates a phenomenon that has been observed in the lab as well as at the Camel site. The long lockstitch seams stress the bobbin reserves of thread. Bobbin thread runout is a common occurrence that requires operator diligence to respond with as little wasted seaming as possible. The figure shows a reduction in **TMR** prior to total loss of bobbin thread. This is assumed to be caused by low tension in the bobbin thread allowing the top thread to pull up higher in the seam. The bobbin may have already unwound at this point. Finally, the top thread finds no bobbin thread to hold it in the seam, thus eliminating the interlocking loop in the seam. The **TMR** value remaining reflects the thread usage caused by the feed dogs advancing the fabric and pulling top thread along the top of the fabric. With appropriate limits, bobbin runout could be detected. Bobbin thread runout has always been detectable with no difficulty.

In the long seam environment at Camel, there was considerable interest in having such a detector for bobbin runout with other defects being above minimum requirements.

Visit to Site #2 : Levi Strauss

The plant trial was undertaken at the Levi's plant in Knoxville, TN. This plant is the largest Levi's sewing facility. Introductions at the plant were made personally by Gene Croyle from the Levi's R & D Center in Richardson, TX. Levi's R & D has had an interest in the results of this project and provided advice on general considerations from the inception of this project. While much effort is going into diverse areas such as ergonomics in the workplace, the R & D Center has been a leader in innovation and automation of apparel processes. The R & D team was quite aware of the 68HC811 processor which was the heart of the defect detector. As part of the research effort, a full description of the circuit was given to the Levi's research team.

During the Knoxville in-plant tests, Lincoln Milsaps, Maintenance Manager, provided direct supervision of efforts within the plant. Assisting with sewing and machine set-up were Bill Williamson, Mike McNeilly, and Greg Carter. The plant was under an unusually heavy backlog of work at the time of the visit and the available machine was a cuff hemmer. The machine turned the bottom hem and formed a straight cuff with a lockstitch seam.

The set-up of this demonstration took an unusually long time because of recurring irregularity in the **TMR** trace. Mechanics worked on the machine and replaced a broken part. Nevertheless, the inconsistencies continued. Now it appears that we were working with worn feed dogs that allowed fabric slip (affecting net **TMR**) and stitch to stitch variation. There may have been thread problems compounding the issue. Data was collected with a group size of twenty. This reduced the variance such that a partially effective demonstration could be made. This consumed some five hours of plant time.

Figure 3. following comes from the Levi's site visit.

Site #2 LEVI DEMONSTRATION
Machine with Intermittent operation

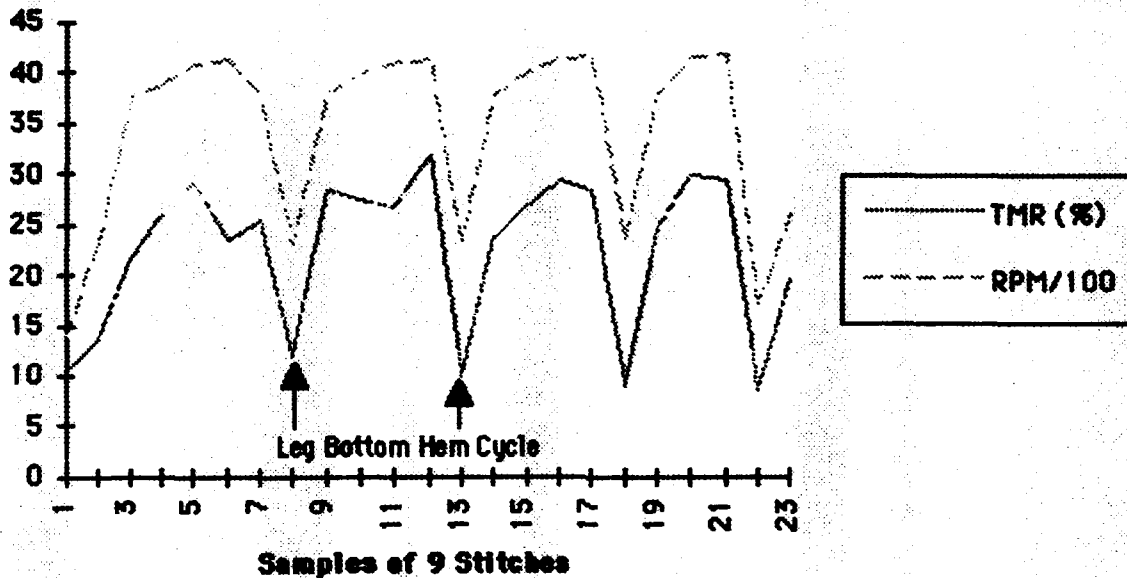


Figure 3. Data from Levi Plant Visit

This particular machine also had worn bearings and loose parts such that vibration was much higher than average. The smooth nature of the data in Fig. 3 belies the true nature of the raw data. The group averages were of 20 raw data points. The goal was to have reasonable four sigma limits (not the entire span of the graph.) Also, we noted that the value of **TMR** was higher than we had ever measured in any previous test. This observation suggests that the top thread was not following the usual path in the fabric. Mr. Milsaps agreed that this machine was an unfair test bed and a secondary choice with controllable speed was identified. The data from previous tests was presented to the Levi's group so that they could see the successes which have been seen elsewhere. By this time the shift was coming to an end as was our trip. The return to this plant at some time in the future is a strong desire of the research team.

Visit to Site #3 : Russell Corporation

Russell Corporation is a major supplier of knit goods for athletic and recreational use. They have sport apparel for general consumer use ranging from very high end wear to simple tee and sweat shirts. The headquarters is in Alexander City, AL. While plants are scattered today in a variety of locations, the plant trials at Russell were conducted at the Mechanical R & D Center and at the Training Center. Russell is a very progressive company with respect to automation of processes. Our preliminary contact was with Merrill Caldwell and Mike Mann at the R & D Center in the year or two before this visit. A good background in what we were trying to do was established in the early visits as well as receiving insight as to how the design approach should be taken. On this visit the demonstration occurred with the following persons attending: Mike Mann, Manager of Electronics Engineering, Fletcher Adams, Vice President of R & D, Phil Thomas, Director of Mechanical R & D, and Alan Knox, Electrical Engineer. Fletcher Adams gave some insight to the reliability issues and importance of this type of work to global competitiveness. Mike Mann noted that a lot of development at Russell had been with Intel and other microprocessors, yet it was not overly difficult to deal with the Motorola line of microprocessors.

Information was given to us about the general approach to having a "first board" drawn out and fabricated. Also, discussion was held on the design of this board and estimation of costs for producing populated boards of a similar complexity. As with Levi's R & D, the full schematic, parts descriptions, and programming were presented to Mike Mann and Alan Knox. At both Russell and Levi's, the research groups were already deeply involved in a number of specialty projects for the sewing plants. It would be difficult for either to break away to do a design / test/ production sequence necessary to get the board into their plants. Mike Mann said that they and most manufacturers would much prefer to buy proven hardware over constructing it at home. Of course, only a very few apparel manufacturers could consider building an electronic device of any type internally.

The first tests undertaken at Russell were done on a bottom hemming machine. As set up for this test, it was doing the bottom hem in a light to medium weight tee shirt using a type 406 stitch. A major problem in plant with this machine is that the bottom thread passes near the rotating shaft which actuates the bottom looper in forming this particular chain stitch. On regular occasions the thread is caught on the rotating shaft and winds continuously into an ever increasing ball of yarn.

Where an operator is present, there are no problems normally, except that the machine has to be taken out of service for removal of the ball of thread. The shaft is finished especially smooth to help resist wrapping-up. When the shaft is cleaned, often a knife must be used to cut the thread free. This leaves the shaft burred or less smooth than original, and more liable to wrap-up a second and third time.

When an operator is not present, as with automated processes, then no one is available to stop the formation of an ever increasing diameter of thread ball. This carries on until the frame of the sewing head is broken, essentially rendering the sewing head useless. At two to three thousand dollars per sewing head, this is a prohibitive expense and a deterrent to automation. There is no detector presently capable of picking up the thread run-on condition that accompanies the shaft wrap-up problem. Russell was and is ambitiously searching for a resolution to the problem. The first trials were pointed to testing the detector for resolution of this problem.

After setting up the demonstration gear, the test was conducted by passing the bottom thread through a hand held guide and walking away from the machine while it was sewing. This simulated continuous withdrawal of bottom thread during the sewing process as happens when wrap-up occurs. The result was a clearly detectable loss of TMR caused by the fact that no pulse from the Eltex unit occurred during the machine cycle. Therefore, TMR dropped to zero. This is a very easily detectible condition and was spotted every time that it occurred.

Data from this part of the Russell visit is typified by the "borrowed" data which is given in Figure 4.

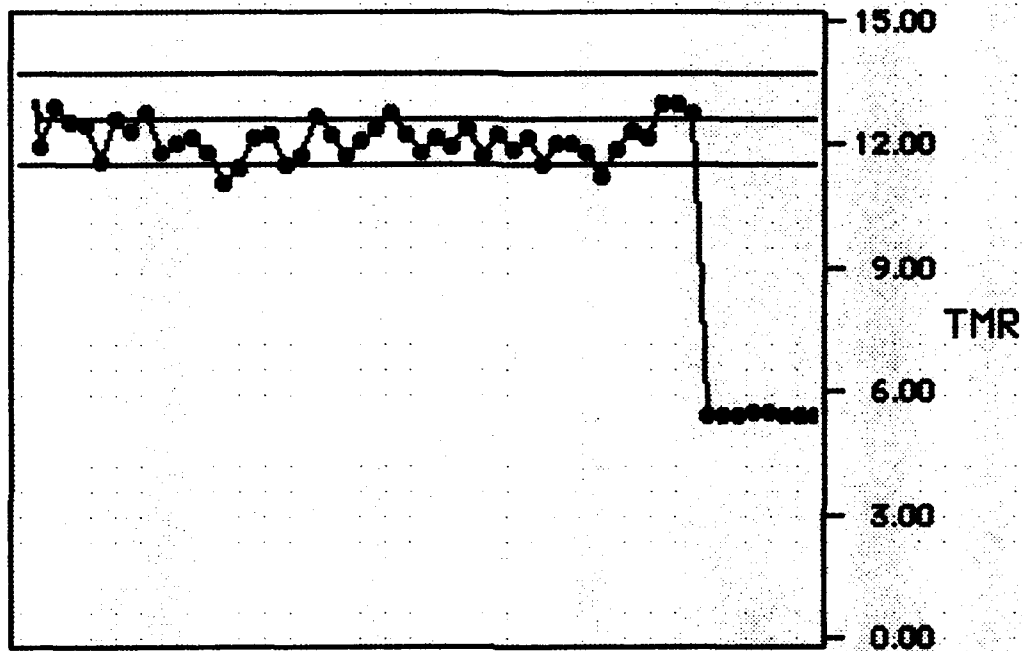


Figure 4. Typical Appearance of Wrap-up Condition

Every simulated wrap-up was detected. This clearly would be useful on an automated sewing line. While the interest was there to proceed immediately, the question was asked if the detector could be expanded to sample both the top thread and the bottom thread at the same time. The response to that question is that the current microprocessor is at its limit on accomplishing the tasks of its program in the time available. To sample more threads would require greater speed. The Russell staff was interested in this line of attack being followed by the Georgia Tech group.

Russell concluded that the trial on the bottom hemmer was a success, and while partially acceptable as is, would be completely acceptable if it monitored both input thread-lines. There was great interest in our moving to a

second problem area which was the overedge sewing operation. To do this test, the system was broken down at the Mechanical R & D Center and transported to the Training Center.

The overedge sewing head on which the next tests were performed was a Union Special machine. This is the type 504 stitch. The machine was in very good condition and maintained by the training center manager.

The overedger is a three thread sewing machine. It passes two threads over the edge of the garment and uses one additional thread to complete the so called "delta", whose balance is quite important to first quality seams. The tests included determining what could be found about loss of thread and thread tension imbalance which might lead to imbalance of the "delta". Figure 5. illustrates the overedge data.

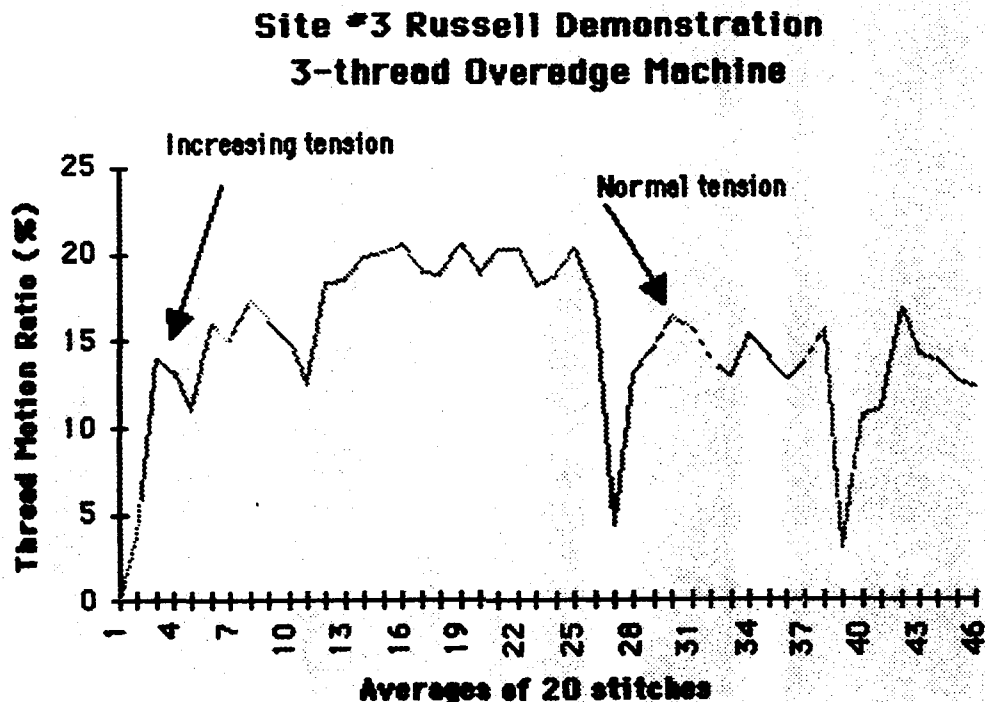


Figure 5. Overedge Tension Variations

Tension changes were clearly observable as changes in TMR. Some tests were made to see if changes in tension

on a second or third of the threads could be seen in the thread being sampled. While small variations followed changes in any thread (probably due to the balance of the "delta" being off set), there was a clear need to monitor each thread to be certain that the machine was running properly. Figure 6. gives additional information on the tests, namely a thread break.

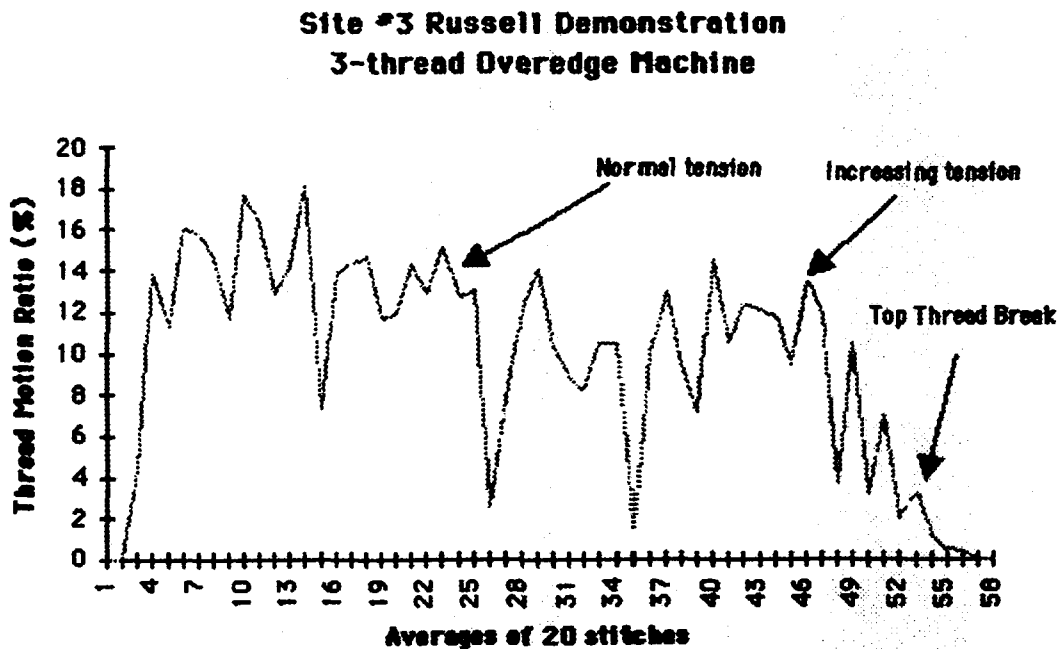


Figure 6. Top Thread Break

The need for multiple thread monitoring is especially apparent in automated processes where a break in one of the three threads should result in a clear change. The tests showed that thread breaks probably would be detected, but individual monitoring would bring this probability up to a certainty.

One observation was that more experience was needed on the unusual stitch types (unusual being relative since past experience has been with lockstitch sewing.) The good point was all that the research team saw behaved

reasonably. Figure 7. shows 20 stitch groupings as part of an effort to smooth the data.

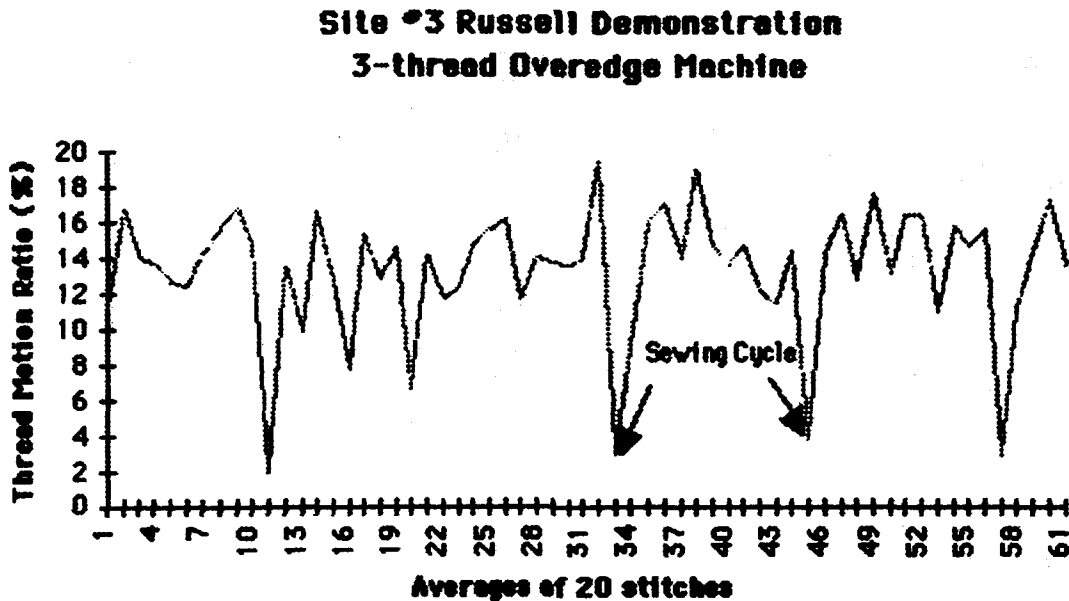


Figure 7. Normal Stitches with Needle Thread

Machine stops and length of cycle are additional measurable quantities. On all three threads of the overedge stitch sewing head, there was clear indication of a thread break when it occurred. Thread tension change when significant enough to change the balance of the "delta", also produced an out of limit condition on the detector.

Conclusions

With three thread monitoring, normal fault detection on multiple threadlines and a contention type of system could be implemented wherein if one sensor determined a fault condition existed, the other one or two (or more) detectors could be checked for confirmation of the

finding. If not confirmed, then an additional data set be required before shutting down the process. When the idea of multiple thread monitoring was discussed at Levi's R & D Center, one of the electrical engineers mentioned a new chip just now commonly available, the Motorola 68HC816 microprocessor. It has twice the register (32 bits) and data bus size (16 bits) and twice the speed (16 MHz) of the 68HC811. It is comparable in instruction set.

A significant part of the IEEE math routine code is devoted to handling the pieces of 32 bit quantities both in memory and while doing arithmetic in the registers. This new chip simplifies that process, meaning less code will do the same thing. And it does it twice as fast. The conjecture is that this chip will hold the capability needed for a new concept in the thread monitor. Ideally, a four thread sensing and monitoring capability offers greatest generality.

The new concept is to have such a four thread monitor with switches at each thread sensor to enable or disable that position. This would provide the single system which could be moved from machine to machine or installed without regard to the specific machine type. This is possible due to the learn feature which allows differing thread consumption rates to be handled as individuals. The plant may elect to use the RS-232 data capability in a networked control system, or to bypass that section of the code as well. Clearly, this is what is needed to bring the system to a generally applicable level where both technically inexperienced and experienced sewing plants may take advantage of the technology.